UNIVERSITY OF TURKISH AERONAUTICAL ASSOCIATION
INSTITUTE OF SCIENCE AND TECHNOLOGY

EFFECT OF FLIGHT SIMULATOR OUT THE WINDOW VISUAL DATABASE ON PERCEPTION OF ALTITUDE AND SPEED IN LOW LEVEL FLIGHT

MASTER THESIS

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Department of Engineering Management

Master of Science in Engineering Management Program

AUGUST 2017

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Thesis Defense Date: 14 August 2017

INSTITUTE OF SCIENCE AND TECHNOLOGY OF
THE UNIVERSITY OF TURKISH AERONAUTICAL ASSOCIATION

I hereby declare that all the information in this study I presented as my Master's Thesis, called "Effect of Flight Simulator out the Window Visual Database on Perception of Altitude and Speed in Low Level Flight" has been presented in accordance with the academic rules and ethical conduct. I also declare and certify on my honor that I have fully cited and referenced all the sources I made use of in this present study.

14.08.2017
Şafak TULUMOĞLU

PREFACE

The thesis, *Effect of Flight Simulator out the Window Visual Database on Perception of Altitude and Speed in Low Level Flight* aims to analyze the effect of resolution change and model density change on perception of altitude and speed. The study has been conducted to fulfill the graduation requirements of the Engineering Management graduate program at the University of Turkish Aeronautical Association. I have been engaged in researching and reporting the findings in this thesis since October 2016.

My research question was formulated together with my supervisor, Asst. Prof. Dr. Hasan Umut Akın. In this research, it was challenging to collect information and investigate the effect of different visual databases on pilot's visual perceptions. Fortunately, I was able to overcome the problems with the help of my supervisor.

I would like to start my acknowledgement statements by thanking my supervisor for his excellent guidance, broad vision and incredibly useful advice during this process to complete my thesis. I am grateful to Hulusi Baysal for his contribution to the maturation of my thesis, to Ahmet Birol Çavdar, and Başar Kasım for their motivation support and advice. My wife, Hülya Tulumoğlu, deserves the greatest thanks because of her extra dedication in the care of our children and her motivation support.

I dedicate this thesis to my wife and my children, for times I am not able to bring back.

August, 2017 Şafak TULUMOĞLU

CONTENTS

TABLES

FIGURES

ABBREVIATIONS

AOPA	: Aircraft Owners and Pilots Association
CIG	**:** Computer-Image Generator
CS FSTD	: Certification Specifications for Flight Simulation Training Devices
DEM	: Digital Elevation Model
EASA	: European Aviation Safety Agency
FFS	: Full Flight Simulator
FPS	: Frames-Per-Second
GOF	: Global Optical Flow
GPL	: General Public License
HDD SVS	: Head Down Display Synthetic Vision Systems
IG	: Image Generator
LAF	: Low Altitude Flight
OTW	**:** Out the Window
ZFTT	: Zero Flight Time Training

ABSTRACT

EFFECT OF FLIGHT SIMULATOR OUT THE WINDOW VISUAL DATABASE ON PERCEPTION OF ALTITUDE AND SPEED IN LOW LEVEL FLIGHT

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Master, Department of Engineering Management

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August-2017, 57 pages

It is very important that the simulations shall contain the necessary visual cues so that the acquired flight skills can be transferred to the real world positively. Therefore, the detail level of out the window (OTW) visual scene of flight simulators becomes more important when low altitude flight (LAF) missions are performed. Limited computer-image generator (CIG) processing capacity places constraints on the details of simulator visual scenes.

The purpose of this study is to investigate the effect of OTW visual database of flight simulators on perception of altitude and speed in LAF. For this purpose, recorded flights on different OTW visual databases which differs on terrain texture resolution and number of 3D models resting on it are shown to the participants to request them for judging on the change of altitude and speed of the flight. The results are evaluated to see the effects of the visual scene details on altitude and speed in LAF. It is assessed that the result of the study helps visual database creators determining the detail level of visual scene in terms of its resolution and the number of 3D models in it.

Keywords: Low altitude flight, altitude cues, visual cues, visual simulation, flight simulator, aviation, terrain texture resolution, three-dimensional objects

ÖZET

UÇUŞ SİMÜLATÖRLERİNDEKİ DIŞ DÜNYA GÖRSEL VERİTABANI ÇÖZÜNÜRLÜĞÜNÜN ALÇAK UÇUŞTA YÜKSEKLİK VE HIZ ALGISINA ETKİSİ

TULUMOĞLU, Şafak

Yüksek Lisans, Mühendislik Yönetimi Anabilim Dalı

Tez Danışmanı: Asst. Prof. Dr. Hasan UMUT AKIN

Ağustos-2017, 57 sayfa

Simülatör eğitiminde, uçuş becerilerinin gerçek dünyaya olumlu şekilde aktarılabilmesi için simülasyonun gerekli görsel ipuçlarını içermesi çok önemlidir. Bu nedenle, uçuş simülatörlerindeki dış dünya görsel sahnesinin ayrıntı seviyesi, alçak irtifa uçuş görevleri gerçekleştirildiğinde daha da önem kazanmaktadır. Görüntü üreteçlerindeki sistem performansı kısıtları dış dünya görsel veri tabanının detay seviyesinin belirlenmesinde önemli rol oynamaktadır.

Bu çalışmanın amacı, uçuş simülatörlerindeki dış dünya görsel veri tabanının alçak irtifa uçuşlarındaki yükseklik ve hız algılamasına etkisini araştırmaktır. Bu amaçla, farklı arazi dokusu çözünürlüklerinde ve farklı sayıda üç boyutlu modele sahip görsel araziler üzerinde yapılan uçuşlar kaydedilerek katılımcılardan uçuşun yükseklik ve hız değişimleri hakkında yargıda bulunmaları talep edilmiştir. Elde edilen sonuçlar, alçak irtifa uçuşlarda dış dünya görsel sahne detaylarının yükseklik ve hız algısı üzerindeki etkilerini görmek için değerlendirilmiştir. Bu çalışmanın sonucunun, görsel veri tabanı yaratıcılarına dış dünya görsel sahnesinin ayrıntı düzeyini belirlemesinde yardımcı olacağı değerlendirilmektedir.

Anahtar Sözcükler: Alçak uçuş, irtifa işaretleri, görsel ipuçları, görsel simülasyon, uçuş simülatörü, havacılık, arazi dokusu çözünürlüğü, üç boyutlu nesneler.

CHAPTER ONE

1. INTRODUCTION

Low altitude flight, a tactical flight, is a flight of military pilots trying to get rid of enemy radars. Such flights are usually carried out at an average speed of around 450 knots and at altitudes between 100 and 500 feet (Kleiss, & Hubbard, 1993). At LAF, because of being very close to ground, minor faults cause unwanted major hazards.

According to one of the article of Burnside, published in November 2016 on Aviation Safety Magazine, evaluating the results of AOPA (Aircraft Owners and Pilots Association) Air Safety Institute's 25th Joseph T. Nall Report, 74 percent of non-commercial aircraft accidents recorded in 2013 were related to pilotage. A significant proportion of those pilot-related accidents comprise of low altitude flights, which are associated with control loss and obstacle encounters.

Flight simulators have begun to develop at the end of the 1960s and early 1970s to improve the technical flight capability of pilots. LAF training is one of the flight experience that earned by pilots in these simulators. Figure 1.1 shows an example of full flight simulators used for pilot training.

First flight simulators were able to fly by instruments and did not have a visual system. Nowadays, flight simulators are so advanced that civil pilots can convert their pilot's licenses from one airliner type to another by flying on simulators only. This type of training is called as zero flight time training (ZFTT). To convert a pilot's license through ZFTT, of course, it is necessary that the simulators should be a full flight simulator (FFS) with the highest standard which is Level D. A Level D type simulator is an exact replica of the respective aircraft/helicopter type that has been proven by objective and subjective tests. EASA (European Aviation Safety Agency) is a European organization that defines the regulations for both helicopter and aircraft flight simulators and certifies them. According to the CS FSTD (Certification

Specifications for Flight Simulation Training Devices) rules defined by this organization, visual system is one of the must systems that a FFS with the highest standard should have (EASA, 2012).

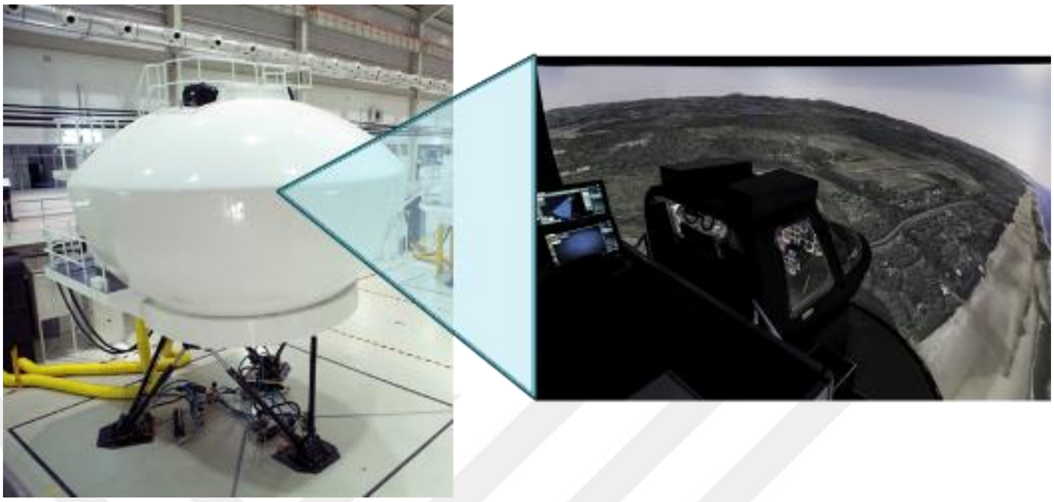

Figure 1.1: Full Flight Simulator.

A modern visual system has three main parts, which are an image generator (IG), projection system and a collimated optical system where to place the image in front of the pilot(s). The function of the IG is to generate the visual scene. Figure 1.2 shows a few sample of OTW visual scenes used in visual systems of flight simulators. In simulator training, it is crucial that the simulation include the necessary visual cues in order to transfer flight skills to the real world positively (Gray, 2007). Therefore, the detail level of out the window visual scene of flight simulators becomes more important when low altitude flight missions are performed. Pilots mostly rely on visual cues from the outside world to check their altitude when flying at low altitudes. Unfortunately, in low altitude flight tasks performed in flight simulators, the effectiveness of the training activity is limited to detail level of visual databases used in simulators, because they contain little information in terms of altitude visual cues (Kleiss et al., 1988).

Figure 1.2: Flight Simulator OTW Visual Scenes.

Though imaginary of visual database advanced with the development of technology, power of the computers is still main concern. Since the processing capacity of computer-image generators (CIG) is limited, it places constraints on the details of flight simulator visual scenes. According to the tests conducted by Latger et al. (2012), increasing the number of polygons drawn by graphics card to 3 times reduces the frame rate by about 3 times and increasing the number of pixels drawn by graphic cards by 25% reduces the frame rate by about 15%.

In this work, the effect of OTW visual database on perception of altitude and speed in low altitude flight is evaluated. It is assessed that the result of the study helps visual database creators determining the detail level of visual scene.

In the next chapter, the literature summary of the previous studies are given. In the third chapter, the materials and methods used in the study are explained. The analyzes made and the results obtained are discussed in the fourth chapter. In the fifth and final chapter, the conclusion and recommendations are given.

CHAPTER TWO

2. LITERATURE REVIEW

Many different methods have been developed for the creation of the OTW visual scene. Previous simulators used computer-generated complex textures for terrain surfaces (Figure 2.1). For the three-dimensional models, they used tetrahedrons, pine trees (Figure 2.2), and boxes (Figure 2.3).

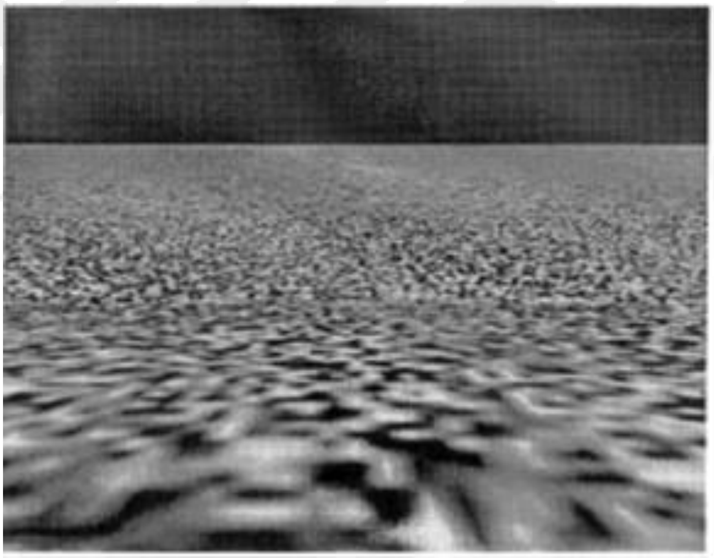

Figure 2.1: Computer-generated complex textures (Winterbottom et al., 2001).

Figure 2.2: Tetrahedrons and pine trees (Kleiss, & Hubbard, 1993).

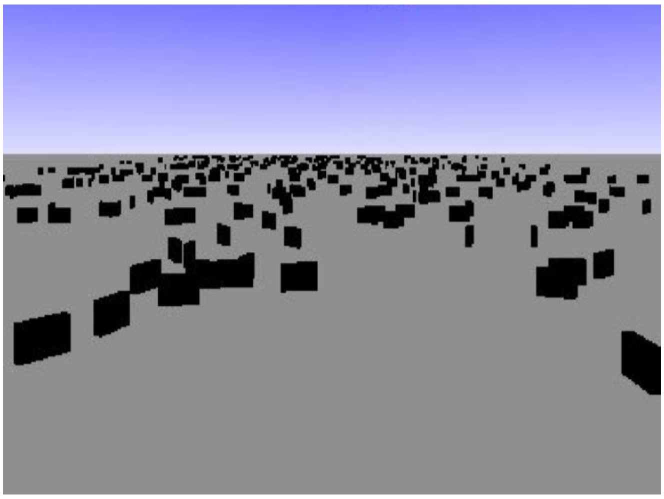

Figure 2.3: 3D Boxes (Gray, 2007).

With the development of technology, in most modern flight simulators, the terrain is covered with high resolution satellite images (Figure 2.4). For the three-dimensional models, truth-like 3D objects are used with the actual size and location (Figure 2.5).

Figure 2.4: Satellite image.

Figure 2.5: Truth-like 3D objects.

Providing correct cues in flight simulators is vital to support high-level decision-making (Maran, & Glavin, 2003). Therefore, creating more realistic OTW visual scene is important for flight simulators. There are numerous studies/researches regarding the effect of visual scene details on perception of altitude in LAF found in the literature. Table 2.1 shows the comparison of the selected studies on the effect of visual scene details on perception of altitude in LAF.

Kleiss et al. (1988) found that object density was a more important factor in simulated LAF than object type by comparing object detail and object density. In 1993, Kleiss and Hubbard investigated the effects of three different types of visual scene detail (object density, the natural appearance of objects, and the presence of complex texture on terrain surfaces) used in flight simulators on detection of altitude change. According to their research, object density and texture on terrain surfaces affected performance somewhat independently, whereas the natural appearance of individual objects had no effect at all.

The effect of terrain shape and object grouping in determining altitude change at low altitudes in flight simulators was investigated by Kleiss in 1994. The result of the investigation indicated that the detection of altitude change was positively affected by the shapes of terrain surfaces and grouping of objects. One year later, in 1995, he tried to determine the characteristics of visual scenes related to simulation of LAF. His results showed that the shape of terrain surfaces and object size or grouping are two different properties of visual scenes.

Garness et al. (1994) evaluated the ability of subjects to maintain a steady altitude as a component of the structure in the optical flow field in which optic flow (the distribution of distinct motion of brightness pattern in a scene, arising from relative motion of scene and viewers (Gibson 1950, 1966; Horn, & Schunck, 1981)) was controlled by utilizing four distinct ground surface types (splay angle, depression angle, random dot, and block textures) crossed with two global optical flow (GOF) rates (0 and 3 eyeheights/s). The result of their research supported their theory that the value of specific textures as data transporters to control altitude depends on the level of GOF.

Table 2.1: Comparison of the selected studies on the effect of visual scene details on perception of altitude in LAF.

Reference	Main Purpose	Participants	Result
Kleiss, Curry, & Hubbard (1988)	Compare the object detail or object density to determine which one is more important factor in simulated LAF.	24 male pilots. 4 of them had 2,500 to 4,500 hours, others had 350 to 1,600 hours of flying time.	Object density was a more important factor than object type.
Kleiss & Hubbard (1993)	The effects of object density, the natural appearance of objects, and the presence of complex texture on terrain surfaces on detection of altitude change.	**Experiment 1:** 24 male pilots. 9 of them had 1350 hours the mean of flying time, other's data lost. **Experiment 2:** 12 male pilots with 938 hours mean total flying time. **Experiment 3:** 10 male pilots with 1174 hours mean total flying time.	Object density and texture on terrain surfaces affected performance somewhat independently, whereas the natural appearance of individual objects had no effect at all.
Kleiss (1994)	Investigating the effect of terrain shape and object grouping to determine altitude change at low altitudes in flight simulators.	4 female subjects (mean age = 33, between the ages 25 and 42) and 8 male subjects (mean age = 28.86, between the ages 18 and 43, 2 of them were pilots).	The detection of altitude change was positively affected by shapes of terrain surfaces and grouping of objects.
Garness, Flach, Stanard, & Warren (1994)	Evaluating the ability of subjects to maintain a steady altitude as a component of the structure in the optical flow field.	20 males with no prior flight experience.	The value of specific textures as data transporters to control altitude depends on the level of GOF.

Table 2.1 (Continued): Comparison of the selected studies on the effect of visual scene details on perception of altitude in LAF.

Reference	Main Purpose	Participants	Result
Kleiss (1995)	Determining the characteristics of visual scenes related to simulation of LAF via video tapes or photos of real-world scenes featuring a variety of scenes.	**Experiment 1:** 16 pilots. 10 of them had 4170 hours mean total flying time and 6 of them 3642 hours mean total flying time. **Experiment 2:** 32 pilots. 9 of them had 896 hours mean total flying time and remaining had 1329 hours mean total flying time.	The shape of terrain surfaces and object size or grouping are two different properties of visual scenes.
Winterbottom, Geri, Pierce, & Harris (2001)	Using LAF performance to evaluate the effectiveness of the texture density cues (perceived texture density, optical flow rate, and optical edge rate) used in high fidelity flight simulators.	11 observers, 2 of them were authors, between the ages of 18 and 55.	Increased optic flow has an effect on altitude deviation when airspeed increased. Edge rate is not a major visual cue for performing the altitude maintenance task and texture density is apparently not a limiting factor in providing altitude cues in high fidelity simulators.
Lemos, Schnell, Etherington, Vogl, & Postikov (2003)	Deciding the impact of DEM resolution along with a set of terrain textures and shading techniques on performance and workload in a HDD SVS.	**Experiment 1&2:** Non-pilot participants. **Experiment 3:** Pilot participants.	High resolution images produced high performance and low workload and the effect of terrain texture on the level of performance changed according to task. In terms of shading factor, Gouraud-shaded images were supported in terms of high performance and low workload.

Table 2.1 (Continued): Comparison of the selected studies on the effect of visual scene details on perception of altitude in LAF.

Reference	Main Purpose	Participants	Result
Patterson, Geri, Dyre, Akhtar, Covas, & Pierce (2005)	The effects of manipulating the properties of 3D objects and terrain texture on the control of altitude in simulated flight.	8 non-pilot observers having no flight experience.	The error in controlling altitude was relatively low when either natural terrain or 3D objects, or both, were present.
Gray (2007)	Systematically varying the visual scene content (from simple 2D textures to 3D objects) in attempt to vary the salience of the 2D and 3D visual cues to altitude maintenance in LAF.	6 participants.	Varying the regularity and height of surface elements on the ground terrain had a substantial effect on altitude maintenance performance.
Gray, Geri, Akhtar, & Covas (2008)	Investigating the use of visual occlusion as a cue to altitude maintenance in LAF.	**Experiment 1,3,4:** 6 participants, one of them was author, were between the ages of 19 and 32. **Experiment 2:** 4 participants, one of them was author and none of them had participated in Experiment 1, between the ages of 18 and 47.	There appears to be an important trade-off between both object height and object density, and object radius and object density. If it is necessary to have a simulation with low object density, it is suggested that good LAF performance can be maintained by using taller and/or wider objects.

In order to evaluate the effectiveness of the texture density cues which are used in high fidelity flight simulators, LAF performance was used by Winterbottom et al. (2001). They used simple ground textures to determine whether the visual cues (perceived texture density, optical flow rate, and optical edge rate) provided by such textures could be used to perform altitude maintenance during LAF. They showed that increased optic flow has an effect on altitude deviation when airspeed increased. Edge rate is not a major visual cue for performing the altitude maintenance task and texture density is apparently not a limiting factor in providing altitude cues in high fidelity simulators.

In 2003, Lemos et al. designed a study to decide the impact of Digital Elevation Model (DEM) resolution along with a set of terrain textures and shading techniques on performance and workload in a Head Down Display Synthetic Vision Systems (HDD SVS). They showed that high resolution images produced high performance and low workload and the effect of terrain texture on the level of performance changed according to task. In terms of shading factor, they showed that Gouraud-shaded images were supported in terms of high performance and low workload.

Patterson et al. (2005) investigated the effects of manipulating the properties of 3D objects (varying the density and width of buildings, e.g., the number and length of horizontal contours) and terrain texture (the presence and absence of texture) on the control of altitude in simulated flight and showed that the error in controlling altitude was relatively low when either natural terrain or 3D objects, or both, were present. The presence of 3D objects and/or real-world terrain texture can improve performance on an altitude-control task. A similar research was done by Gray in 2007. He systematically varied the visual scene content (from simple 2D textures to 3D objects) in attempt to vary the salience of the 2D and 3D visual cues to altitude maintenance in LAF and found that varying the regularity and height of surface elements on the ground terrain had a substantial effect on altitude maintenance performance.

In 2008, Gray et al. investigated the use of visual occlusion as a cue to altitude maintenance in LAF. The results of their study showed that there appears to be an important trade-off between both object height and object density, and object radius and object density. If it is necessary to have a simulation with low object density, they suggest that good LAF performance can be maintained by using taller and/or wider objects.

Most of the researches mentioned above, except Patterson et al. (2005), used computer-generated complex textures for the terrain surfaces. Patterson et al. (2005) used real-world terrain texture only to see the differences between the presence and absence of terrain texture. The objects used in those researches were usually tetrahedrons and pine trees. The visual scene generation of the newly flight simulators are improved with the development of the technology. In most modern flight simulators, the terrain of the external flight environment displayed to pilots is covered with high resolution satellite images and truth-like 3D objects resting on it.

Unfortunately, limited CIG processing capacity limits the usage of high resolution images and truth-like 3D objects on all terrain surfaces. To have a better performance, rarely used terrain surfaces are covered with low resolution images and only important buildings are modeled as truth-like 3D objects. This study is mainly focused on the effect of resolution change of terrain image and density of truth-like 3D objects resting on it.

Early researches on visual cues focused primarily on the perception of altitude but not speed. This study is also mainly focused on using visual scene which is generated with new technological facilities and investigating the effect of visual scene on perception of speed, besides altitude.

CHAPTER THREE

3. MATERIALS AND METHODS

In this study, it is proposed to enrich the studies done before by replacing the methods for simulating terrain surfaces and 3D objects and adding speed perception to the study. Throughout this work, *Microsoft Excel* (Spreadsheet Software Programs | 2016) and *IBM SPSS Statistics* (IBM Statistical Software Program | Trial Version) are used for editing and analyzing data.

3.1. Visual Test for Altitude and Speed Perception

To evaluate the effect of resolution change of terrain image and density of truth-like 3D objects on altitude and speed perception of participants, a visual test was prepared. The following subsections describe the stages of preparing the test.

3.1.1. Selection of Visual Databases

To evaluate the effects of visual scene details on perception of altitude and speed, six different OTW visual databases which differ on terrain texture resolution and number of 3D models resting on it were specified. The locations of the visual databases are around Utah in United States. Three of those visual databases does not include any 3D models and differ from each other according to their image resolutions level. The resolution levels of those terrains are 10 meters (Figure 3.1), 1 meter (Figure 3.2) and 0.25 meter (Figure 3.3), respectively. Other three of the specified visual databases differ from each other according to their 3D model counts resting on them. They have about 14, 27 and 50+ number of 3D models resting on them, respectively and they are called as few (Figure 3.4), medium (Figure 3.5) and high number (Figure 3.6) of 3D object visual databases.

Figure 3.1: 10 meters resolution terrain.

Figure 3.2: 1 meter resolution terrain.

Figure 3.3: 0.25 meter resolution terrain.

Figure 3.4: Terrain with few number of 3D objects.

Figure 3.5: Terrain with medium number of 3D objects.

Figure 3.6: Terrain with high number of 3D objects.

3.1.2. Recording Flights

For the low altitude flight values, 100, 200, 300, 400 and 500 feet altitudes are specified as flight altitudes and 350, 400, 450, 500 and 550 knots are specified as flight speeds, since in a document of 162nd Tactical Fighter Group (1986) it is stated that fighter-type aircraft routinely fly at altitudes between 100 and 500 feet above ground level with speeds in the vicinity of 450 knots (Kleiss & Hubbard, 1993). To understand the effect of OTW visual scene detail on detection of altitude change, flight videos at the specified altitude levels at same speed were recorded on each specified terrain database. Similarly, to understand the effect of OTW visual scene detail on detection of speed change, flight videos at the specified speeds at same altitude were recorded on each specified terrain database. Flights are executed by using a real-time image generation software platform which is producing high-fidelity 3D graphics at 60 frames-per-second (FPS), for use in a variety of simulation and training applications including Level D type flight simulators (MANTIS Image Generation Software, http://quantum3d.com/mantis/ | Free Version). To execute the image generator at 60 Hz, a computer platform satisfying the minimum hardware requirements was needed. Therefore, the computer platform given the specifications below was selected.

- Windows 10 Home 64 bit
- Intel Core i7-4720HQ CPU @ 2.60 GHz
- 16.0 GB RAM
- NVIDIA GeForce GTX 970M
- 1920 x 1080 resolution monitor

To record the flights, *Fraps*, a universal Windows application that can be used with games using DirectX or OpenGL graphic technology, was used. It can capture audio and video up to 7680x4800 with custom frame rates from 1 to 120 frames per second (http://www.fraps.com/ | Free Version). The flights were recorded at 60 fps and 1920 x 1080 resolution. Each recorded flight takes time about 10-12 seconds.

3.1.3. Preparing Flight Videos

Since the real-time capture tool records the data as raw format without compression, the size of the recorded videos was too big, about 750-800 MB, to process. Therefore, *Any Video Converter Free*, a free video conversion tool (http://www.anvsoft.com/any-video-converter-free.html | Free Version), was used to reduce the size of the videos by compressing and converting to the H.264/MPEG-4 AVC compression format which is one of the most commonly used formats for the recording, compressing, and distributing video content (Ozer, 2016). The formatted videos have the size about 7-8 MB. The formatted videos are, then, cropped by using *Windows Movie Maker* which is a discontinued video editing software by Microsoft (http://windows.microsoft.com/en-us/windows-live/movie-maker | Freeware), and each flight record has six seconds long.

3.1.4. Creating Test Questions

To evaluate the effects of different visual databases on perception of altitude and speed, a web based test was created on Microsoft Forms which provides to create tests and surveys to collect information and works on any web browser (https://forms.office.com/). The test consists of two main parts and 60 questions. Pilots were asked to answer randomly ordered 30 altitude questions in the first part, and randomly ordered 30 speed questions in the second part. Prior to the video questions, pilots were asked to watch the sample flight videos recorded at different speeds and altitudes on each visual database in order to familiarize with the visual databases. The link of the test and the explanation of questions are given in Appendix A.

Every question in the first section consists of two videos. Six previously identified visual databases (three of them varying according to resolutions and three of them varying according to model density) were randomly distributed among these questions. In each question, first video, taking time for six seconds, is shown to pilots, followed by two seconds black screen, and then second video, taking time for six seconds is shown to pilots. Pilots were asked to compare the altitude of the second flight video with the flight altitude of the first video and to choose between "Second flight is higher", "Second flight is lower" or "Two flight altitudes are same". Flight speeds of each flights in question videos are fixed and 450 knots. Flight altitude of first video in each question is 300 feet. Flight altitude of second videos vary randomly from 100 feet to 500 feet. Figure 3.7 shows the flow diagram of the flow described above.

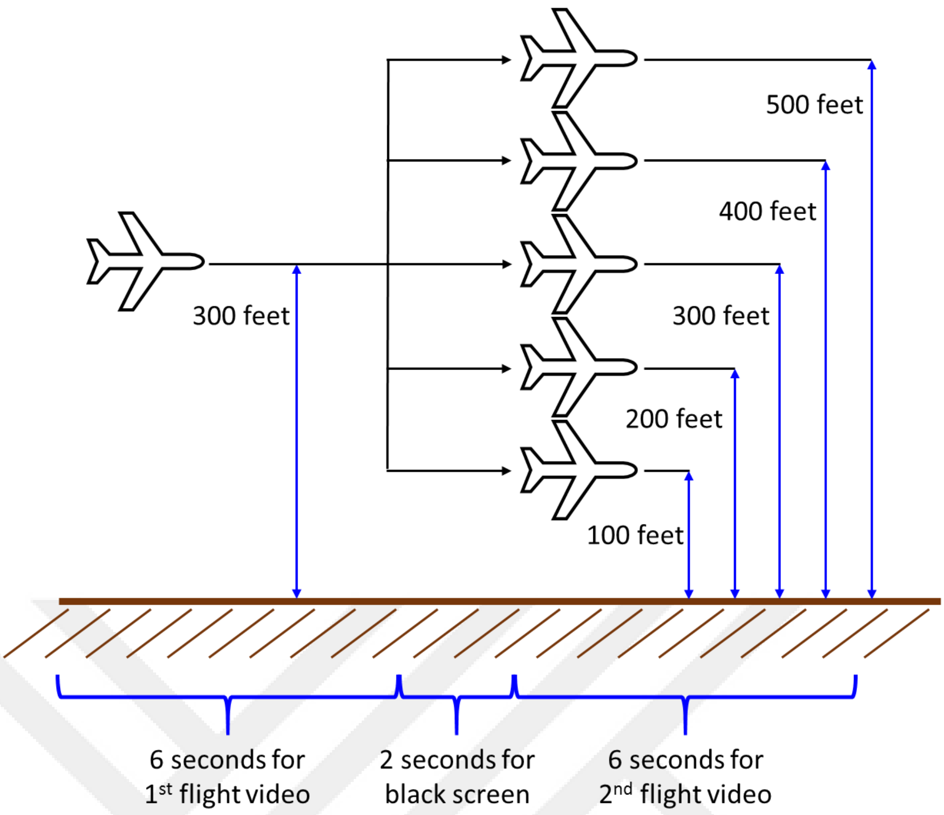

Figure 3.7: Section one question flow.

The video questions in the second section are similar to the questions in the first section. All questions consist of two videos. In this section, also, the visual databases are distributed randomly among questions. In each question, as in the first part questions, first video, taking time for six seconds, is shown to pilots, followed by two seconds black screen, and then second video, taking time for six seconds is shown to pilots. Pilots were asked to compare the speed of the flight in the second video with the flight speed in the first video and choose between "Second flight is faster", "Second flight is slower" or "Two flights have same speed". The flight altitudes in these questions are fixed at 300 feet. The flight speed of the first video in each question is 450 knots and the flight speeds of the second videos are randomly changing between 350 knots and 550 knots. Figure 3.8 shows a flow diagram of the flow described herein.

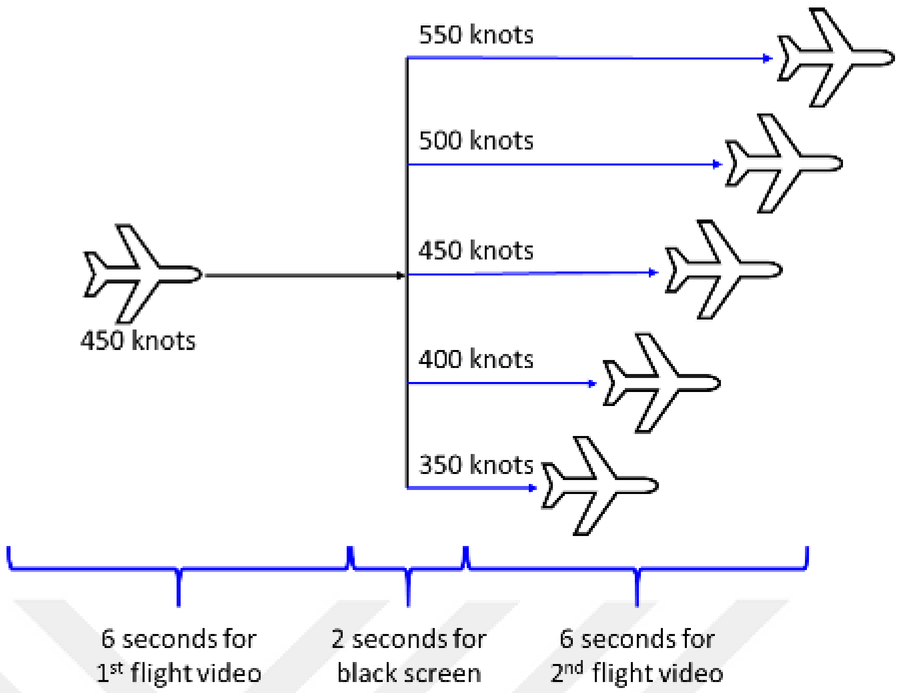

Figure 3.8: Section two question flow.

3.2. Profiles of Participants

33 male pilots who served in military and civil aviation participated to the test between 17 April and 10 June 2017. Pilot's total flight experiences vary between 145 hours and 15100 hours. Flight platforms that pilots experienced are helicopter, propeller and jet aircrafts. Six of the pilots are pilot candidates who have only flight experience with propeller training aircrafts. 21 of the pilots have helicopter flight experience changing between 2500 and 7600 hours. The number of pilots with propeller aircraft flight experience is 23. Flight experience of those pilots vary between 36 and 3400 hours. Nine of the pilots have jet aircraft flight experience changing between 155 and 9000 hours. Eight of them have both helicopter and propeller aircraft flight experience, six of the pilots have both propeller and jet aircrafts flight experience, and three of them have helicopter, propeller and jet aircrafts flight experience. The summary of the pilot's flight experience is given in Table 3.1. Some of the pilots fly with more than one platform therefore the total of the number of platforms exceeds the total number of pilots participated to test.

Table 3.1: Pilot’s Flight Experience Summary

Flight Platform	The Number of Pilots	Flight Experience
Helicopter	21	2500 – 7600 hours
Propeller Aircraft	23	36 – 3400 hours
Jet Aircraft	9	155 – 9000 hours
Helicopter and Propeller Aircraft	8	2536 – 7720 hours
Propeller and Jet Aircrafts	6	950 – 8500 hours
Helicopter, Propeller and Jet Aircrafts	3	10420 – 15100 hours

When the pilots are classified according to the their flight platform that they mostly flight, it is seen that there are 19 helicopter pilots, seven propeller aircraft pilots and seven jet aircraft pilots.

The age of the pilots varies from 23 to 59. The number of pilots between the ages of 23 and 30 is six. Five of them are candidate pilots and one of them is jet aircraft pilot. four of the pilots are between the ages of 31 and 40. One of them is candidate pilot, two of them are jet aircraft pilots and one of them is propeller aircraft pilot. The number of pilots between the ages of 41 and 50 is nine. Eight of them are helicopter pilots and one of them is jet aircraft pilot. The remaining pilots, whose number is 14, are between 51 and 59 years old. 11 of them are helicopter pilots and three of them are jet aircraft pilots.

Figure 3.9 presents the age and flight experience distributions of the participants. From the chart, it is seen that the number of pilots flying with helicopter is higher than the pilots flying with propeller and jet aircrafts. The flight experiences gained on helicopter and jet aircrafts is much higher than the flight experience gained on propeller aircraft. According to the chart, also, the majority of participating pilots are over 40 years of age. The detailed information about the pilots’ experiences is given in Appendix B.

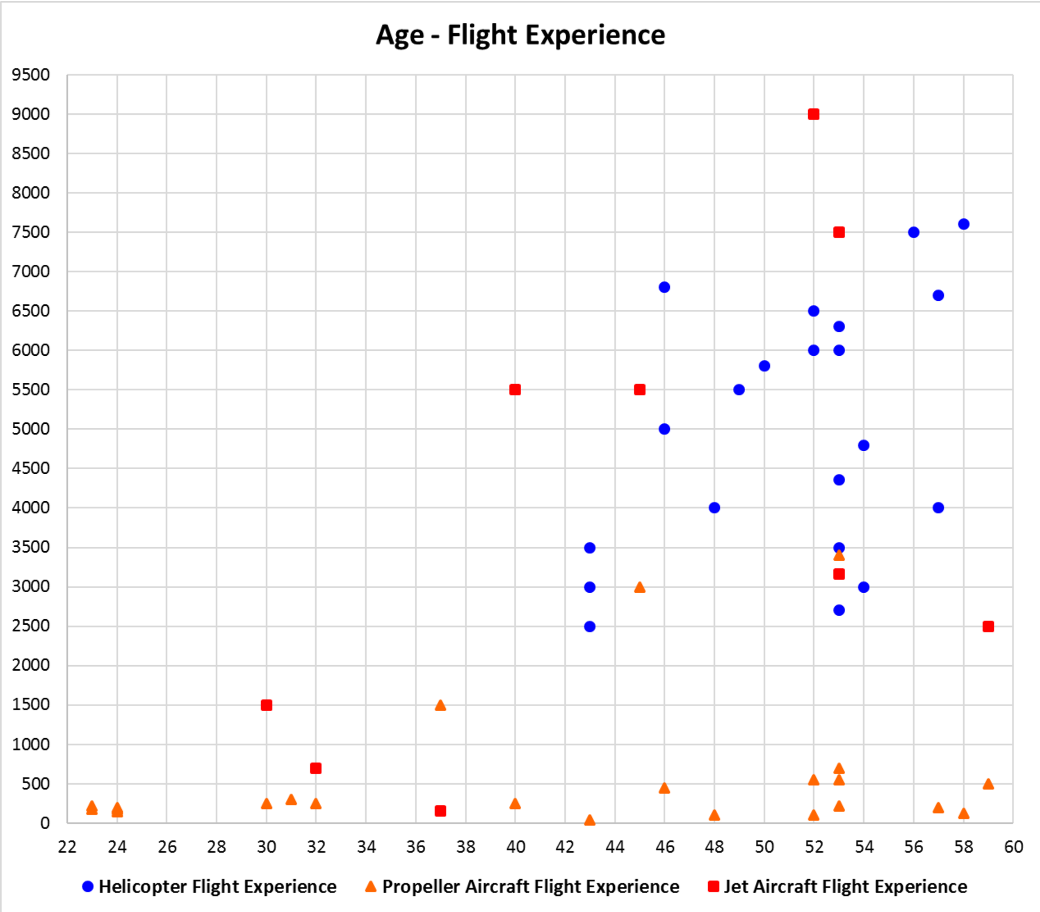

Figure 3.9: Age - Flight experience distribution of participants.

CHAPTER FOUR

4. RESULTS AND DISCUSSION

In this thesis, the effect of resolution and model densities on perception of altitude and speed was investigated. Six different visual databases, three of them having different resolution levels and three of them having different model densities, were specified. On those visual databases, various flights, having five different altitudes and five different speeds, were recorded. With those visual records, a 60-question web-based test was created for pilots to perceive altitude changes and speed changes. 33 pilots having different flight experiences were involved to this test in about one and half month. Answers of the participants are given in Appendix C.

Firstly, the correct answers given by pilots for altitude and speed questions are analyzed according to relationship with the pilots' flight experiences. Section 4.1 explains the analyses carried out in this context. In the analyses, the altitude and speed questions were evaluated separately. For simplicity, the number of correct answers given for the altitude and speed questions are mentioned as "Altitude" and "Speed", respectively.

In section 4.2, the analyses carried out to understand the relationship between the correct answers and different visual databases and flight characteristics were explained. Again, the number of correct answers given by pilots for altitude and speed questions were analyzed separately and mentioned as "Altitude" and "Speed", respectively. In the analyses, also, the visual databases were separated into two groups; visual databases changing according to the resolution and the number of 3D models resting on them. For simplicity, the visual databases changing according to the resolution, which are 10 m, 1m and 0.25 m resolution visual databases, are mentioned as "Resolution" and the visual databases changing according to the number of 3D models, having few, medium and high number of 3D models, are mentioned as “Model Density”.

In this thesis, there was not a chance to apply tests on a flight simulator. In order to reach more pilots, a web-based test was applied. For future work, this test can be repeated on a flight simulator to get more accurate results.

4.1. Test Results Analysis According to Pilot Features

Firstly, the number of correct answers given by pilots for altitude and speed questions were analyzed according to the pilots’ age and flight experiences. The correlations between the flight experiences of the participants and the correct answers given for the altitude and speed questions were identified to assess the relationships. The correlation table is given in Figure 4.1.

According to the correlation table, there is a small negative correlation between the age of participants and the number of correct answers given by pilots for speed questions, r = -0.17. An increase in helicopter flight experience is little correlated with a decrease in the number of correct answers given for altitude questions and moderately correlated with a decrease in the number of correct answers given for speed questions, r = -0.15 and r = -0.32, respectively. These results can be explained with age. As age increases, flight experience increases, however; altitude and speed perception decrease. In contrast to helicopter flight experience, an increase in Propeller aircraft flight experience little leads to an increase in the number of correct answers given for speed questions, r = 0.15, and an increase in Jet aircraft flight experience little leads to an increase in both the number of correct answers given for altitude and speed questions, r = 0.29 and r = 0.25, respectively. Between the number of correct answers given for altitude and speed questions, there is a moderate positive correlation, r = 0.36. Pilots giving correct answers to altitude questions mostly gave correct answers to speed questions.

The frequency and amount of training in flight simulators of pilots vary depending on many criteria including used flight platforms, pilot type (instructor pilot, military pilot, civil pilot, etc.) and working place. These results may be explained by considering previous simulator trainings; however, there is not enough and necessary data for this.

	Age	Helicopter F.E.	Propeller Aircraft F.E.	Jet Aircraft F.E.	Total F.E.	Altitude	Speed
Age	1						
Helicopter F.E.	0,75	1					
Propeller Aircraft F.E.	0,07	-0,16	1				
Jet Aircraft F.E.	0,16	-0,12	0,32	1			
Total F.E.	0,70	0,66	0,30	0,64	1		
Altitude	-0,07	-0,15	-0,08	0,29	0,06	1	
Speed	-0,17	-0,32	0,15	0,25	-0,05	0,36	1

Figure 4.1: Correlation table between participant characteristics and correct responses to altitude and speed questions. (F.E.: Flight Experience)

In order to determine if there were differences in pilot's main flight platforms, pilot's age and pilot's total flight hours, an independent-samples t-test was run on the number of correct answers given for altitude and speed questions. Data are mean ± standard deviation, unless otherwise stated. According to their main flight platform, pilots are divided into three category which are "Helicopter" pilots, "Aircraft" pilots and "Pilot Candidates". There were 18 Helicopter pilots, 9 Aircraft pilots and 6 pilot candidates. An independent-samples t-test was run between these categories for each altitude and speed correct answers and only statistical significant difference is seen between Helicopter and Aircraft pilots for the correct answer of speed questions. The output of the test is shown in Figure 4.2. The number of correct answers for speed questions given by Aircraft pilots (21.22 ± 3.83) was higher than the number of correct answers given by Helicopter pilots (17.56 ± 4.59), $t(19) = -2.19$, $p = 0.02$.

Speed		
t-Test: Two-Sample Assuming Unequal Variances		
	Helicopter	*Aircraft*
Mean	17,56	21,22
Variance	21,08	14,69
Std. Deviation	4,59	3,83
Observations	18	9
Hypothesized Mean Difference	0	
df	19	
t Stat	-2,19	
P(T<=t) one-tail	0,02	
t Critical one-tail	1,73	
P(T<=t) two-tail	0,04	
t Critical two-tail	2,09	

Figure 4.2: T-test for correct answers of speed questions by main platform.

An independent-samples t-test was conducted according to the altitude and speed correct answers given by the participants grouped by age. In this analyzes, six pilot candidates who were young and only having propeller aircraft experience were excluded. Participants are divided into two groups according to their age: 45 years old and over and under 45 years old. There is a total of 20 participants aged 45 and over and a total of seven participants below 45 years of age. When the results are analyzed, it is found that altitude perception under the age of 45 (23.57 ± 3.87) is better than the age 45 years old and over (20.20 ± 4.15), t(11) = -1.95, p = 0.04. The t-test table is given in Figure 4.3. However, there is no significant difference between the two groups in terms of the correct answers to the questions about the speed perception.

Altitude t-Test: Two-Sample Assuming Unequal Variances		
	Age >= 45	*Age < 45*
Mean	20,20	23,57
Variance	17,22	14,95
Std. Deviation	4,15	3,87
Observations	20	7
Hypothesized Mean Difference	0	
df	11	
t Stat	-1,95	
P(T<=t) one-tail	0,04	
t Critical one-tail	1,80	
P(T<=t) two-tail	0,08	
t Critical two-tail	2,20	

Figure 4.3: T-test for correct answers of altitude questions by age.

Finally, when the participants are grouped by total flight experience, again pilot candidates are excluded. There are 15 participants with a total of 5000 hours or more of flight experience and 12 participants with a total of 5000 hours of flight experience. An independent-samples t-test was applied to these groups, the result is that the total flight experience does not have much effect on the correct answers given for the altitude and speed questions.

4.2. Test Results Analysis According to Visual Databases and Altitude/Speed Relationship

The answers given by pilots are divided into four group according to the altitude and speed questions on the visual database categories which are resolution and model density. Figure 4.4 and Figure 4.5 shows the percentage of correct answers for each level of resolution or model density as a function of altitude or speed. Predictably, perception of altitude changes was more accurate with larger changes in altitude for both resolution and model density visual databases and the trends of percentage correct answers on different altitude changes are similar for both those visual databases. According to both resolution – altitude and model density – altitude graphs, the perception of descent is higher than the perception of ascension and the lowest perception of altitude change occurs when flight ascent from 300 feet to 400 feet.

According to the resolution – speed and model density – speed graphs, perception of speed changes shows similar trends except for 1 m and 0.25 m resolution visual databases. The percentage of correct answers increases when change of speed increases or speed does not change.

Mostly, detections for altitude and speed changes are minimum for highest resolution visual database which is 0.25 m. The perception of altitude changes for 10 m and 1 m visual databases are close to each other except for large ascent changes, on which low resolution gives better result.

Detection of altitude on model density visual databases is higher for high number of 3D model visual database than others. For perception of speed changes, high number of 3D model visual database gives higher results for the percentage of correct answers for deceleration questions than other 3D model visual databases, however it gives lower results for percentage of correct answers for acceleration cases.

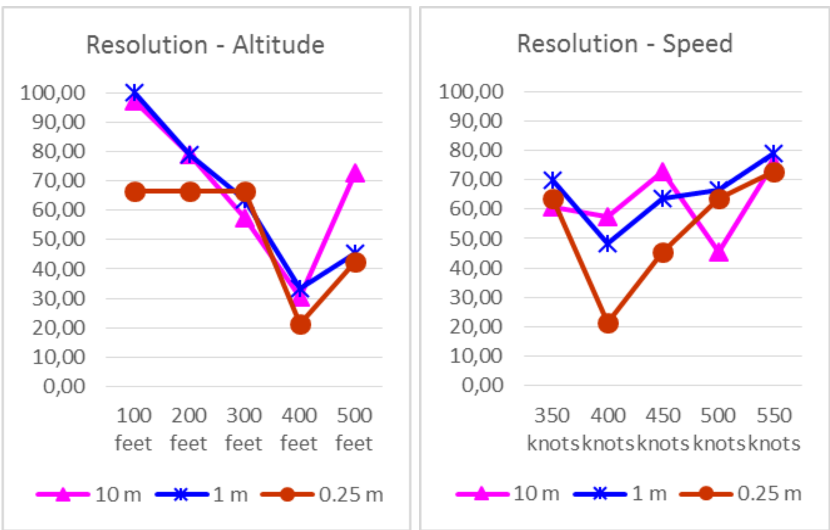

Figure 4.4: Graphs of perception of altitude and speed on visual databases changing according to resolution.

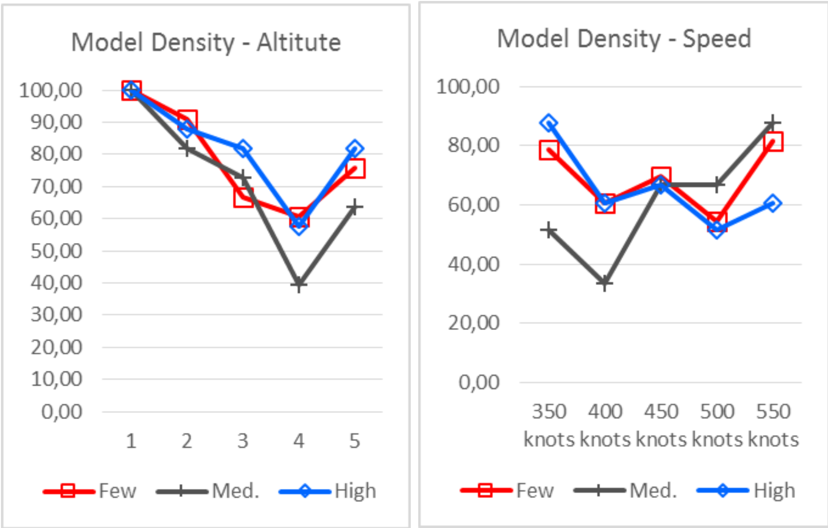

Figure 4.5: Graphs of perception of altitude and speed on visual databases changing according to model density.

Four one-way ANOVAs were conducted to examine the effects of altitude and speed changes on the percentage of correct answers given by pilots to the questions. Pilot candidates are excluded from these analyses. Least Significant Difference (LSD) post hoc analysis was carried out for all pairwise comparisons.

Figure 4.6 shows the result of ANOVA analysis for altitude questions on visual databases having different resolutions. The basic hypotheses of interest in ANOVA are as follows:

H_0: The means of correct answers for altitude questions on visual databases having different resolutions are equal

H_1: At least one mean of correct answers for altitude questions on visual databases having different resolutions is different

The percentage of correct answers given to different altitude questions on resolution visual databases was significantly different, $F(4,10) = 10.57$, $p = 0.001$. In general, perception of descent was more accurate than perception of elevation. The highest number of correct answers were given to descent to 100 feet questions and the lowest number of correct answers were given to ascent to 400 feet questions. Therefore; LSD post hoc test revealed that the most significant difference was between the correct answers given to 100 and 400 feet questions. There was no significant difference between the correct answers given to flights 200 and 300 feet, 100 and 200 feet, and 300 and 500 feet.

Resolution - Altitude Analysis						
Anova: Single Factor						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
100 feet	3	2,630	0,877	0,033		
200 feet	3	2,296	0,765	0,007		
300 feet	3	1,889	0,630	0,001		
400 feet	3	0,889	0,296	0,001		
500 feet	3	1,667	0,556	0,026		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0,588	4	0,147	10,569	0,001	3,478
Within Groups	0,139	10	0,014			
Total	0,727	14				

LSD Post Hoc Test		
100ft vs 400ft	0,580	Reject NULL Hypotheses (H_0)
200ft vs 400ft	0,469	Reject NULL Hypotheses (H_0)
300ft vs 400ft	0,333	Reject NULL Hypotheses (H_0)
100ft vs 500ft	0,321	Reject NULL Hypotheses (H_0)
400ft vs 500ft	0,259	Reject NULL Hypotheses (H_0)
100ft vs 300ft	0,247	Reject NULL Hypotheses (H_0)
200ft vs 500ft	0,210	Reject NULL Hypotheses (H_0)
200ft vs 300ft	0,136	Do not Reject NULL Hypotheses (H_0)
100ft vs 200ft	0,111	Do not Reject NULL Hypotheses (H_0)
300ft vs 500ft	0,074	Do not Reject NULL Hypotheses (H_0)

Figure 4.6: ANOVA Analysis of Altitude Answers on Visual Databases with Different Resolutions.

The result of ANOVA analysis for altitude questions on visual databases with different model densities are given in Figure 4.7. The basic hypotheses of interest in ANOVA are as follows:

H_0: The means of correct answers for altitude questions on visual databases having different number of 3D model in it are equal.

H_1: At least one mean of correct answers for altitude questions on visual databases having different number of 3D model in it is different.

The percentage of correct answers was significantly different between different altitude flights on 3D model visual databases, $F(4,10) = 33.70$, $p < 0.0005$. As in the resolution visual databases, perception of descent was generally more accurate than perception of elevation. The highest number of correct answers were given to 100 feet questions and the lowest number of correct answers were given to 400 feet questions.

LSD post hoc test revealed that there was no significant difference between the correct answers given to flights 300 and 500 feet, however; there was a significant difference between all other flights. The most notable difference was between the flights 100 and 400 feet, as in the visual databases in different resolutions.

Model Density - Altitude Analysis

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
100 feet	3	3,000	1,000	0,000
200 feet	3	2,667	0,889	0,000
300 feet	3	2,185	0,728	0,002
400 feet	3	1,556	0,519	0,004
500 feet	3	2,296	0,765	0,009

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0,395	4	0,099	33,703	0,000	3,478
Within Groups	0,029	10	0,003			
Total	0,424	14				

LSD Post Hoc Test

100ft vs 400ft	0,481	Reject NULL Hypotheses (H_0)
200ft vs 400ft	0,370	Reject NULL Hypotheses (H_0)
100ft vs 300ft	0,272	Reject NULL Hypotheses (H_0)
400ft vs 500ft	0,247	Reject NULL Hypotheses (H_0)
100ft vs 500ft	0,235	Reject NULL Hypotheses (H_0)
300ft vs 400ft	0,210	Reject NULL Hypotheses (H_0)
200ft vs 300ft	0,160	Reject NULL Hypotheses (H_0)
200ft vs 500ft	0,123	Reject NULL Hypotheses (H_0)
100ft vs 200ft	0,111	Reject NULL Hypotheses (H_0)
300ft vs 500ft	0,037	Do not Reject NULL Hypotheses (H_0)

Figure 4.7: ANOVA Analysis of Altitude Answers on Visual Databases with Different Model Densities.

When looking at ANOVA results above, the percentage of correct answers given for altitude changes on visual databases changing depending on the resolution and model density shows statistically significantly differences. These two visual database categories were compared with the paired samples t-test in order to understand which visual database altitude variations were perceived more accurately (Figure 4.8). Data are mean ± standard deviation, unless otherwise stated. According to the results, the altitude variations on the visual databases varying according to the model density (78.02 ± 18.13) were perceived statistically significantly more correctly than the ones on the visual database varying according to the resolution (62.47 ± 22.13), t(4) = -6.176, p = 0.002.

t-Test: Paired Two Sample for Means		
	Resolution	*Model Density*
Mean	62,47	78,02
Variance	489,61	328,79
Std. Deviation	22,13	18,13
Observations	5	5
Pearson Correlation	0,98	
Hypothesized Mean Difference	0	
df	4	
t Stat	-6,18	
P(T<=t) one-tail	0,002	
t Critical one-tail	2,13	
P(T<=t) two-tail	0,003	
t Critical two-tail	2,78	

Figure 4.8: Paired t-test for percentage of correct answers on resolution model density visual databases.

ANOVA test results of speed questions on resolution visual databases are given in Figure 4.9. The basic hypotheses of interest in ANOVA are as follows:

H_0: The means of correct answers for speed questions on visual databases having different resolutions are equal.

H_1: At least one mean of correct answers for speed questions on visual databases having different resolutions is different.

The percentage of correct answers was significantly different between different speed flights on resolution visual databases, F(4,10) = 5.13, p = 0.016. In general, perception of deceleration was less accurate than perception of acceleration. The highest number of correct answers for speed questions on resolution visual database were given to accelerate to 550 knots questions and the lowest number of correct answers for speed questions on resolution visual database were given to decelerate to 400 knots questions. Therefore; LSD post hoc test revealed that the most significant difference was between the correct answers given to 400 and 550 knots questions. There was no significant difference between the correct answers given to flights 450 and 500 knots, 350 and 450 knots, and 350 and 500 knots.

Resolution - Speed Analysis						
Anova: Single Factor						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
350 knots	3	1,852	0,617	0,009		
400 knots	3	1,111	0,370	0,029		
450 knots	3	1,778	0,593	0,022		
500 knots	3	1,926	0,642	0,013		
550 knots	3	2,444	0,815	0,001		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0,302	4	0,076	5,130	0,016	3,478
Within Groups	0,147	10	0,015			
Total	0,449	14				
LSD Post Hoc Test						
400kt vs 550kt	0,444	Reject NULL Hypotheses (H_0)				
400kt vs 500kt	0,272	Reject NULL Hypotheses (H_0)				
350kt vs 400kt	0,247	Reject NULL Hypotheses (H_0)				
400kt vs 450kt	0,222	Reject NULL Hypotheses (H_0)				
450kt vs 550kt	0,222	Reject NULL Hypotheses (H_0)				
350kt vs 550kt	0,198	Reject NULL Hypotheses (H_0)				
500kt vs 550kt	0,173	Reject NULL Hypotheses (H_0)				
450kt vs 500kt	0,049	Do not Reject NULL Hypotheses (H_0)				
350kt vs 450kt	0,025	Do not Reject NULL Hypotheses (H_0)				
350kt vs 500kt	0,025	Do not Reject NULL Hypotheses (H_0)				

Figure 4.9: ANOVA Analysis of Speed Answers on Visual Databases with Different Resolutions.

Figure 4.10 shows the result of ANOVA analysis for speed questions on visual databases having different 3D model counts. The basic hypotheses of interest in ANOVA are as follows:

H_0: The means of correct answers for speed questions on visual databases having different number of 3D model in it are equal.

H_1: At least one mean of correct answers for speed questions on visual databases having different number of 3D model in it is different.

As in the resolution visual databases, the highest number of correct answers for speed questions on model count visual databases were given to accelerate to 550 knots questions and the lowest number of correct answers for speed questions on model count visual databases were given to decelerate to 400 knots questions, however; the differences between the correct answers given for different speed questions on varying model count visual databases was not statistically significant, F(4, 10) = 2.016, p = 0.168.

Model Density - Speed Analysis						
Anova: Single Factor						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
350 knots	3	2,074	0,691	0,036		
400 knots	3	1,407	0,469	0,007		
450 knots	3	2,000	0,667	0,001		
500 knots	3	1,926	0,642	0,009		
550 knots	3	2,259	0,753	0,031		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0,136	4	0,034	2,016	0,168	3,478
Within Groups	0,168	10	0,017			
Total	0,304	14				

Figure 4.10: ANOVA Analysis of Speed Answers on Visual Databases with Different Model Densities.

CHAPTER FIVE

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

One of the biggest constraints on flight simulators is the determination of the detail level of the outer world visual scene. It is very important that this level of detail can be determined correctly so that the training given in flight simulators will be closer to the actual flight and the negative trainings given to the pilots will be avoided. For this reason, different approaches and new methods are being tried to create visual databases that describe the outer world with the development of technology.

In this thesis, the effects of density ratios of realistic three-dimensional objects used in the creation of visual models with the resolution of satellite photographs in different levels used as land cover in the creation of the outer world visual scene in flight simulators to altitude and speed perceptions of pilots with different flight experiences were investigated. When the correct answers given by pilots having helicopter experience were examined, as the age increases, the flight experience increases but the altitude and speed perception decrease. The increase in the flight experience on the Jet aircraft platform effects the altitude and speed perceptions on the visual databases positively.

Speed perception of aircraft pilots was higher than the ones of helicopter pilots. There was a decrease in altitude perception rate with increasing age. Altitude perception of pilots under the age of 45 were higher than the ones of pilots being the age 45 years old and over. However; total flight experience does not have much effect on the correct answers given for the altitude and speed questions. Between the correct answers given by pilots having a total of 5000 hours or more of flight experience and the correct answers given by pilots having less than 5000 hours of flight experience, there was no significant difference.

For both resolution and model density visual databases, perception of altitude was more accurate when there was a larger change in altitude. The trends of correct answers for altitude questions are similar for both those visual databases. Perception of speed changes also show similar trends for both resolution and model density visual databases, except for the 0.25 m resolution visual database. Percentage of correct answers increases when change of speed increases or speed does not change. Altitude and speed perceptions were mostly minimum for highest resolution visual database. Except for large ascent change questions, on which low resolution gave better result, altitude perception questions on 10 m and 1 m visual databases gave close results. Altitude perception was higher for high number of 3D model visual database than other 3D model visual databases. For deceleration questions, perception of speed was higher for high number of 3D model visual database than other 3D model visual databases; however, perception of speed was lower for acceleration cases.

For altitude questions on both resolution and model density visual databases, there were significant differences on the perception of altitudes. Perception of descent was more accurate on both resolution and model density visual databases than perception of elevation. The most significant difference was between the correct answers given to 100 and 400 feet questions since the highest and the lowest number of correct answers were given to 100 feet and 400 feet questions, respectively. From the point of view of the significant differences between the correct answer rates given to different flight altitudes, model density seems to be more effective than resolution.

For perception of speed on resolution visual databases, perception of deceleration was less accurate than perception of acceleration. The highest number of correct answers for speed questions on both resolution and model count visual databases were given to 550 knots questions and the lowest number of correct answers for speed questions on both resolution and model count visual databases were given to 400 knots questions. From the point of view of the meaningful differences between the correct answer rates given to different flight speeds, it is seen that the resolution causes a statistically significant effect on speed differences; however, model density does not.

5.2. Recommendations

In this study, to reach more pilots, the tests were applied as web-based and pilots watch the flight videos on a different size computer or tablet screens. In order not to increase the number of questions much, the first flights were fixed and the number of altitude and speed variations in the second flights was limited to five.

Also, the population participating in the test were not active-duty combat pilots. All the experienced ones were retired and some of them are still flying in commercial airlines.

Recommended future studies would be;

- Repetition of the study on simulator training of active-duty pilots on full flight simulators,
- Collecting data obtained by testing various resolution and model density visual database configurations in all kinds of simulator activities at specific intervals and according to task types. This collected data can be used in the following studies;
  - Determining the most appropriate resolution - model density visual database for a specific simulator training,
  - Analyzing the perception change on altitude increase or decrease, and acceleration or deceleration,
  - Analyzing the effect of change of altitude and speed at the same time on perception,
  - Determining the detectable altitude and speed ranges.
- Investigating the effects of the resolution and model density factors on the hardware performance of the simulator.
- Analyzing the effects of newly proposed visual database modelling methods on altitude and speed perception of pilots by using the methods similar to this study.
- Analyzing the effects of size and height of the truth-like 3D models in the same visual database on altitude and speed perception.

REFERENCES

162nd Tactical Fighter Group. (1986). Academic text: Low-altitude training. *Tucson, AZ: Author*.

Anvsoft Inc.(n.d.). *Any Video Converter Free*. Retrieved 01 25, 2017, from Any Video Converter Web Site: http://www.anvsoft.com/any-video-converter-free.html/.

AOPA Air Safety Institute (2016). General Aviation Accidents In 2013. *25th Joseph T.Nall Report*.

Beepa Pty Ltd. (n.d.). *Fraps, Real Time Video Capture & Benchmarking*. Retrieved 12 05, 2016, from Fraps Web Site: http://www.fraps.com/.

Burnside, J. (2016, November), "Low-Level Flying". *Aviation Safety Magazine*. Retrieved 01 2017, from Aviation Safety Magazine Web Site, http://www.aviationsafetymagazine.com/issues/36_11/features/Low-Level-Flying_11259-1.html.

European Aviation Safety Agency. (2012, July). Certification Specifications for Aeroplane Flight Simulation Training Devices. *CS-FSTD(A)*. Initial Issue (pp. 21-25).

European Aviation Safety Agency. (2012, June). Certification Specifications for Helicopter Flight Simulation Training Devices. *CS-FSTD(H)*. Initial Issue (pp. 17-20).

Garness, S. A., Flach, J. M., Stanard, T., & Warren, R. (1994, October). The Basis for the Perception and Control of Altitude: Splay & Depression Angle Components of Optical Flow. *In Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 38, No. 19, pp. 1275-1279). SAGE Publications.

Gibson, J. J. (1950). The perception of the visual world.

Gibson, J. J. (1966). The senses considered as perceptual systems.

Gray, R. (2007, October). 2D vs. 3D Visual Cues for Altitude Maintenance in Low-Altitude Flight. *In Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 51, No. 19, pp. 1287-1290). Sage Publications.

Gray, R., Geri, G. A., Akhtar, S. C., & Covas, C. M. (2008). The role of visual occlusion in altitude maintenance during simulated flight. *Journal of experimental psychology: human perception and performance*, 34(2), 475.

Horn, B. K., & Schunck, B. G. (1981). Determining optical flow. *Artificial intelligence*, 17(1-3), 185-203.

IBM Corp. (2017). IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp.

Kleiss, J. A. (1994, October). Effect of terrain shape and object grouping on detection of altitude change in a flight simulator. *In Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 38, No. 1, pp. 119-123). SAGE Publications.

Kleiss, J. A. (1995). Visual scene properties relevant for simulating low-altitude flight: A multidimensional scaling approach. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, 37(4), 711-734.

Kleiss, J. A., Curry, D. G., & Hubbard, D. C. (1988, October). Effect of three-dimensional object type and density in simulated low-level flight. *In Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 32, No. 18, pp. 1299-1303). SAGE Publications.

Kleiss, J. A., & Hubbard, D. C. (1993). Effects of three types of flight simulator visual scene detail on detection of altitude change. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, 35(4), 653-671.

Latger, J., & Cathala, T. (2012). Image Generator performance and modern HardWare In the Loop stimulation. In *5th International Symposium on Optronics in Defence and Security, Paris, France*.

Lemos, K., Schnell, T., Etherington, T., Vogl, T., & Postikov, A. (2003, October). Synthetic vision systems: human performance assessment of the influence of terrain density and texture. *In Digital Avionics Systems Conference, 2003. DASC'03*. The 22nd (Vol. 2, pp. 9-E). IEEE.

Maran, N. J., & Glavin, R. (2003). Low-to high-fidelity simulation–a continuum of medical education?. *Medical education*, 37(s1), 22-28.

Microsoft. (n.d.). *Microsoft Forms*. Retrieved 04 13, 2017, from Microsoft Web Site: https://forms.office.com/.

Microsoft. (n.d.). *Windows Movie Maker*. Retrieved 02 20, 2017, from Microsoft Web Site: http://windows.microsoft.com/en-us/windows-live/movie-maker/.

Ozer, J. (2016, December). Encoding for Multiple Screen Delivery, Section 3, Lecture 7: Introduction to H.264. *Udemy*.

Patterson, R., Geri, G. A., Dyre, B. P., Akhtar, S. C., Covas, C. M., & Pierce, B. J. (2005). Altitude control in simulated flight using 3-D objects and terrain texture. *Journal of the Society for Information Display*, 13(12), 1039-1043.

Quantum3D. (n.d.). The *MANTIS, Image Generation Software*. Retrieved 11 28, 2016, from Quantum3D Web Site: http://quantum3d.com/mantis/.

Spreadsheet Software Programs. (n.d.). Retrieved 04 03, 2017, from Microsoft Excel Web Site: https://products.office.com/en/excel.

Winterbottom, M. D., Geri, G. A., Pierce, B. J., & Harris, N. M. (2001, October). Low-altitude flight performance as a measure of flight simulator fidelity. *In Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 45, No. 18, pp. 1424-1427). SAGE Publications.

APPENDICES

Appendix A - Link of the Test and the Explanation of Questions

Test questions can be reached from the following web address:

https://forms.office.com/Pages/ResponsePage.aspx?id=nd9XmW5qXkKhmrVJNM6LNMGODfNKl6dKibMTDg5aKylURDBFSE1LNjQ0OTdTQ01HTUZJTllUSEw5Ri4u

Visual Database Perception Test

This test is prepared for master thesis under the supervision of Asst.Prof.Dr. H.Umut AKIN in the Department of Engineering in University of Turkish Aeronautical Association.

In this test, it is asked to answer questions about flights at different speeds and altitudes on visual databases with different resolutions and model densities used in flight simulators. The results will be evaluated to see the effects of the outer world visual scene details on the perception of altitude and speed during low level flights. It is expected that the result of this work will help visual database creators on determining the detail levels of the outer world visual scene.

The test lasts about 20-25 minutes and includes the following questions;

- 5 flight experience questions
- 1 sample flight video
- 2 explanations for questions
- 30 video questions for altitude perception
- 30 video questions for speed perception.

Thank you for completing the test. Do not forget to click submit when you're done!

1

Gender

- ○ Male
- ○ Female

2

Age

[ ]

3

Helicopter Flight Experience (Please write total flight hours, if not please write 0.)

[ ]

4

Propeller Aircraft Flight Experience (Please write total flight hours, if not please write 0.)

5

Jet Aircraft Flight Experience (Please write total flight hours, if not please write 0.)

6

Please watch the following sample video. (You do not need to answer this question.)

To familiarize you with the visual databases, this video includes the sample flight videos on 6 different visual databases used in the following questions. The total video length is 65 seconds.

To make the video fullscreen, after the video starts playing, you can click the "Full screen" icon on the bottom right of the video. To exit full screen mode, press ESC on the keyboard or click on the "Exit full screen" icon on the bottom right of the video. You can stop the video or move it forward or backward.

7

Compare the flights in videos in the 8th - 37th questions according to their flight altitudes. (You do not need to answer this question.)

The purpose of these questions is to measure the effect of resolution and model intensities of the visual databases on the perception of flight altitudes.
Flight Speed: 450 knots
Flight Altitudes: 100 feet, 200 feet, 300 feet, 400 feet, 500 feet

The length of the videos is 14-16 seconds. The content of the videos is as follows;
- First flight video for 6 seconds (flight altitude: 300 feet),
- Black screen for 2 seconds,
- Second flight video for 6 seconds.

To make the video fullscreen, after the video starts playing, you can click the "Full screen" icon on the bottom right of the video. To exit full screen mode, press ESC on the keyboard or click on the "Exit full screen" icon on the bottom right of the video. You can stop the video or move it forward or backward.

38

Compare the flights in videos in the 39th - 68th questions according to their flight speeds. (You do not need to answer this question.)

The purpose of these questions is to measure the effect of resolution and model intensities of the visual databases on the perception of flight speeds.
Flight Speeds: 350 knots, 400 knots, 450 knots, 500 knots, 550 knots
Flight Altitude: 300 feet

The length of the videos is 14-16 seconds. The content of the videos is as follows;

- First flight video for 6 seconds (flight speed: 450 knots),

- Black screen for 2 seconds,

- Second flight video for 6 seconds.

To make the video fullscreen, after the video starts playing, you can click the "Full screen" icon on the bottom right of the video. To exit full screen mode, press ESC on the keyboard or click on the "Exit full screen" icon on the bottom right of the video. You can stop the video or move it forward or backward.

69

Thank you for participating to test. If you want to be informed about the test results, you can enter your e-mail address in the field below.

Appendix B - Detailed Information About the Pilots' Experiences

The detailed information about the pilots' experiences is given in Table B-1.

Table B-1: Detailed Information of Pilots' Experiences

Id	Age	Helicopter Flight Experience (hours)	Propeller Aircraft Flight Experience (hours)	Jet Aircraft Flight Experience (hours)
1	57	4000	0	0
2	56	7500	0	0
3	30	0	250	1500
4	54	3000	0	0
5	31	0	300	0
6	43	2500	36	0
7	53	2700	220	7500
8	53	6300	550	0
9	53	6000	0	0
10	52	6000	100	9000
11	43	3000	0	0
12	53	4360	3400	3160
13	24	0	200	0
14	23	0	220	0
15	23	0	180	0
16	45	0	3000	5500
17	24	0	145	0
18	54	4800	0	0
19	40	0	250	5500
20	32	0	250	700
21	46	5000	0	0
22	46	6800	450	0
23	59	0	500	2500
24	37	0	1500	155
25	43	3500	0	0
26	53	3500	700	0
27	48	4000	100	0
28	49	5500	0	0
29	57	6700	200	0
30	58	7600	120	0
31	50	5800	0	0
32	52	6500	550	0
33	24	0	178	0

Appendix C - Answers of Participants

The answers given by pilots to the altitude questions are given in Table C-1 and the answers given by pilots to the speed questions is given in Table C-2.

Table C-1: The Answers Given by the Pilots to the Altitude Questions

Id	Few-300 ft	0.25 m-200 ft	Few-400 ft	Few-200 ft	Med.-200 ft	Few-500 ft	10 m-300 ft	High-100 ft	High-300 ft	Med.-100 ft	High-400 ft	1 m-500 ft	Few-100 ft	0.25 m-400 ft	1 m-300 ft	1 m-400 ft	10 m-400 ft	1 m-100 ft	1 m-200 ft	0.25 m-500 ft	Med.-400 ft	10 m-100 ft	10 m-500 ft	0.25 m-100 ft	Med.-300 ft	10 m-200 ft	0.25 m-300 ft	Med.-500 ft	High-500 ft	High-200 ft
1	1	0	1	1	0	1	0	1	1	1	1	1	1	0	1	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1	0	0	1	0	1	0	0	1	1	1	0	1	1	1	1	1	1	0	0	1
3	0	1	1	0	0	1	0	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	0	1	0	0	1	1	1
4	1	1	0	1	1	1	1	1	1	1	0	1	1	0	0	0	1	1	1	1	0	1	1	1	1	1	1	1	1	1
5	0	1	0	1	0	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	0	1	1	0	1	0	0	1	1	1
6	0	0	0	1	1	0	0	1	1	1	0	1	1	0	1	0	0	1	1	0	0	1	0	1	1	1	1	0	1	1
7	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1
8	0	1	0	1	1	0	0	1	1	1	0	0	1	0	1	0	0	1	0	0	0	1	1	0	0	0	1	0	1	1
9	1	1	0	1	1	1	0	1	1	1	0	0	1	0	1	0	0	1	0	0	0	0	0	1	1	1	1	0	0	1
10	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	0	1	0	1	1	1
11	0	0	0	1	1	1	0	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1
12	1	0	0	1	1	1	1	1	0	1	1	0	1	0	0	0	0	1	1	1	0	1	1	1	1	1	0	1	1	1
13	0	1	1	1	0	0	0	1	1	1	1	0	1	0	0	0	0	1	0	0	0	1	0	1	1	1	1	0	1	1
14	0	0	1	1	1	1	0	1	1	1	1	0	1	0	0	1	0	1	1	0	0	1	1	1	1	1	1	1	1	1

Table C-1 (Continued): The Answers Given by the Pilots to the Altitude Questions

Id	Few-300 ft	0.25 m-200 ft	Few-400 ft	Few-200 ft	Med.-200 ft	Few-500 ft	10 m-300 ft	High-100 ft	High-300 ft	Med.-100 ft	High-400 ft	1 m-500 ft	Few-100 ft	0.25 m-400 ft	1 m-300 ft	1 m-400 ft	10 m-400 ft	1 m-100 ft	1 m-200 ft	0.25 m-500 ft	Med.-400 ft	10 m-100 ft	10 m-500 ft	0.25 m-100 ft	Med.-300 ft	10 m-200 ft	0.25 m-300 ft	Med.-500 ft	High-500 ft	High-200 ft
15	1	1	1	1	1	1	0	1	1	1	0	1	1	0	0	1	0	1	1	0	0	1	0	0	0	1	1	0	0	0
16	1	0	0	1	0	1	1	1	1	1	1	1	1	0	1	0	0	1	1	1	0	1	0	0	0	1	0	1	1	1
17	1	0	1	1	1	1	1	1	1	1	1	1	1	0	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1
18	1	1	0	1	1	0	1	1	0	1	1	0	1	0	0	0	0	1	1	1	0	1	0	1	0	1	0	1	1	1
19	1	1	1	1	1	1	0	1	1	1	1	0	1	0	1	0	0	1	1	0	0	1	1	1	1	1	1	1	1	1
20	1	0	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
21	1	1	1	1	1	1	1	1	0	1	0	1	1	0	0	0	0	1	1	0	0	1	1	1	0	1	0	1	1	1
22	1	1	1	1	1	1	1	1	1	1	0	0	1	0	1	0	0	1	1	0	0	1	1	0	1	0	1	0	0	0
23	0	0	0	0	1	1	1	1	1	1	0	0	1	0	0	0	0	1	1	0	0	1	1	1	0	1	0	0	1	1
24	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1
25	1	1	1	1	1	1	0	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	0	1	0	1	1	1
26	1	0	1	1	1	1	1	1	1	1	0	0	1	0	1	0	0	1	0	0	0	1	0	1	1	1	1	1	1	1
27	0	0	0	1	1	0	1	1	1	1	1	0	1	0	1	0	0	1	0	0	1	1	0	1	1	1	1	1	1	1
28	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	0	1	1	0	1	1	1	1	1	1	1	1	1	1
29	1	1	0	1	1	0	1	1	1	1	0	0	1	0	1	0	1	1	1	0	0	1	1	0	0	1	1	1	1	1
30	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0	1	0	1	1	0	1	1	1	0	1	1	0	0	1	0
31	1	1	1	1	1	1	0	1	0	1	1	0	1	0	1	1	0	1	0	1	1	1	0	1	1	0	1	0	1	1
32	0	1	0	0	1	0	0	1	1	1	0	0	1	1	0	0	0	1	1	0	0	1	1	0	1	0	0	0	0	0
33	1	1	1	1	0	0	1	1	1	1	0	0	1	0	1	0	0	1	0	0	0	1	1	1	1	0	1	0	0	1

Table C-2: The Answers Given by the Pilots to the Speed Questions.

Id	Few-450 kts	0.25 m-400 kts	Few-500 kts	Few-400 kts	Med.-400 kts	Few-550 kts	10 m-450 kts	High-350 kts	High-450 kts	Med.-350 kts	High-500 kts	1 m-550 kts	Few-350 kts	0.25 m-500 kts	1 m-450 kts	1 m-500 kts	10 m-500 kts	1 m-350 kts	1 m-400 kts	0.25 m-550 kts	Med.-500 kts	10 m-350 kts	10 m-550 kts	0.25 m-350 kts	Med.-450 kts	10 m-400 kts	0.25 m-450 kts	Med.-550 kts	High-550 kts	High-400 kts
1	1	0	1	0	1	1	1	1	0	0	1	1	1	1	0	1	1	0	1	1	1	0	1	1	0	0	1	1	1	0
2	1	0	0	0	0	0	1	0	1	0	1	1	1	1	1	1	0	1	1	1	1	0	1	1	1	1	1	1	0	0
3	1	0	1	0	0	1	0	1	0	0	1	1	0	1	1	1	1	1	0	1	1	1	1	0	0	0	0	1	0	1
4	1	0	0	0	0	1	1	1	0	0	0	1	1	1	1	1	1	1	0	1	1	1	0	0	0	0	0	1	1	0
5	1	1	0	1	0	1	0	1	1	1	0	1	1	0	1	1	0	0	1	0	0	1	0	1	1	1	1	1	1	1
6	0	0	0	1	0	1	1	1	1	0	0	1	0	0	1	0	0	1	0	1	0	0	1	1	1	0	0	1	0	0
7	1	1	1	0	0	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	0	1	1	1	1	1	0	1	1	1
8	0	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	0	1
9	1	0	1	0	0	1	1	1	1	0	1	1	0	1	0	1	1	0	0	1	1	0	1	0	1	0	0	1	1	0
10	1	0	1	1	0	1	1	1	1	0	0	1	1	1	1	0	0	0	0	0	1	0	1	1	1	0	0	1	1	0
11	0	0	1	1	0	1	0	1	1	1	1	1	1	1	0	1	1	0	0	1	1	1	1	0	1	1	0	1	1	1
12	1	0	0	1	0	1	0	0	1	0	1	1	0	1	0	1	1	1	0	1	1	1	1	1	1	1	0	1	1	1
13	1	0	0	1	0	1	1	1	0	0	0	0	1	0	0	0	0	1	1	1	1	1	0	0	0	1	0	1	1	1
14	1	0	1	1	0	1	1	1	0	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
15	1	0	0	1	1	1	0	1	0	1	0	1	1	1	1	1	0	1	1	1	0	1	1	1	1	1	0	0	1	1
16	0	0	1	0	1	1	1	1	1	1	0	1	1	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1
17	1	1	0	1	0	1	1	1	1	1	0	0	1	0	1	0	0	1	1	0	0	1	0	1	0	1	0	1	0	1
18	1	1	1	1	0	1	1	1	0	1	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1	0	1	0	1
19	1	1	0	1	1	0	1	1	1	1	0	1	1	0	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1

Table C-2 (Continued): The Answers Given by the Pilots to the Speed Questions.

Id	Few-450 kts	0.25 m-400 kts	Few-500 kts	Few-400 kts	Med.-400 kts	Few-550 kts	10 m-450 kts	High-350 kts	High-450 kts	Med.-350 kts	High-500 kts	1 m-550 kts	Few-350 kts	0.25 m-500 kts	1 m-450 kts	1 m-500 kts	10 m-500 kts	1 m-350 kts	1 m-400 kts	0.25 m-550 kts	Med.-500 kts	10 m-350 kts	10 m-550 kts	0.25 m-350 kts	Med.-450 kts	10 m-400 kts	0.25 m-450 kts	Med.-550 kts	High-550 kts	High-400 kts
20	1	1	0	1	1	1	1	1	1	1	0	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	1
21	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	1	1	1	1	1	1	1	1
22	1	0	0	0	0	0	1	1	1	1	0	1	0	1	1	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0
23	0	0	1	1	0	0	1	0	1	0	1	1	1	1	0	1	1	1	0	0	1	0	1	0	1	0	0	1	0	1
24	0	0	1	1	1	1	0	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	0	0	1	0	1	1	1
25	1	0	1	0	0	1	1	1	1	0	0	0	0	1	1	0	1	1	0	1	0	1	0	1	1	0	1	1	0	1
26	1	0	0	1	0	1	1	0	1	0	0	0	1	0	0	0	0	0	0	0	1	1	1	1	0	1	1	1	0	0
27	1	1	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	0	0	1	1	1	0	1	1	1	1
28	0	0	1	0	1	1	1	1	0	1	1	1	1	1	0	0	1	1	1	1	1	0	1	1	1	0	0	1	1	0
29	1	0	1	0	1	1	0	1	0	0	1	0	1	1	0	0	0	0	1	0	1	1	1	0	0	1	1	1	1	0
30	0	0	1	1	0	1	1	1	0	0	1	1	0	0	1	1	1	1	0	1	1	0	1	0	0	0	0	1	0	0
31	1	0	1	0	1	1	0	1	0	1	0	1	1	1	1	1	0	0	1	1	0	1	0	0	0	1	0	0	1	0
32	0	0	1	1	0	0	0	1	1	0	0	0	1	0	1	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0
33	1	0	0	1	0	0	1	1	1	0	1	0	1	0	1	1	0	0	0	0	0	1	1	0	1	0	1	1	1	1

RESUME

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